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Review Article

Investigating the True Effect of Psychological Variables Measured Prior to Arthroplastic Surgery on Postsurgical Outcomes: A *P*-Curve Analysis

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Abstract: Patients' presurgical psychological profiles have been posited to predict pain and function following arthroplastic surgery of the hip and knee. Nevertheless, findings are conflicting, and this may be rooted in biased reporting that makes the determination of evidential value difficult. This ambiguity may have negative consequences for researchers and governmental agencies, as these rely on findings to accurately reflect reality. *P*-Curve analyses were used to establish the presence of evidential value and selective reporting in a sample of studies examining the effect of presurgical psychological predictors on outcomes following knee and hip arthroplastic surgery. A systematic search of the literature revealed 26 relevant studies. The examined sets of studies indicate that there is evidential value for the effect of depression on pain intensity and function, anxiety on pain intensity and function, pain catastrophizing on pain intensity, as well as the combined effects of all psychological predictors on pain intensity and function. The presence of evidential value was inconclusive for the effect of optimism on pain intensity. There were no signs that any results were influenced by biased reporting. The results highlight the importance of patients' psychological profiles in predicting surgical outcomes, which represent a promising avenue for future treatment approaches.

***Perspective:* The effects of *P*-hacking are difficult to detect and might be at the root of conflicting findings pertaining to the predictive properties of presurgical psychological variables on postsurgical outcomes. *P*-Curve analysis allows the determination of evidential value underlying these relationships and detection of *P*-hacking to ensure that findings are not the result of selective reporting.**

Key Words: *P-Curve, arthroplasty, depression, optimism, anxiety, function, postsurgical pain, pain catastrophizing.*

Osteoarthritis (OA) is a chronic pain condition that affects roughly 8.75 million people in the UK, with the knee and hip being the most commonly affected sites.[2] Although arthroplasty is considered an effective treatment and, in many cases, a cure for chronic OA-pain, almost 30% of patients undergoing knee or hip replacement surgery develop increased pain and disability, despite objective indicators of surgical success.[7,17,51] Patients' presurgical psychological profiles may play a major role in determining the long-term efficacy of surgery by affecting the recovery process.[13,32,40,45,59,60,68,78-80] Specifically, preoperative levels of fear of pain,[41,79] pain catastrophizing,[22,80,87] depression,[11,20,63,64,68] optimism,[55] self-efficacy,[18,86,88] kinesiophobia,[20] and anxiety[6,20] have been suggested to explain some of the variability in outcomes, such as pain intensity and function, following arthroplasty and may represent promising avenues for future interventions. Nevertheless, there is considerable heterogeneity in these findings, which has cast doubt onto the presence of true effects.[40,87] For example, numerous studies report evidence for the influence of presurgical depressive symptoms on outcomes following arthroplasty, for example,[11,20,63,64,68] while others, for example,[48,59,60,80] report the absence of such effects.

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Aside from methodological differences, such conflicting results may be in part due to publication bias and selective reporting,[36,70,82] which increase the odds of publishing results falsely supporting researchers' hypotheses.[36,82] Intuitively, for each published false-positive result, there should be an even greater number of true-negative results. Conversely, for each false-negative finding, there should be an exceeding number of true-positive results, thus creating a protective ratio of true published findings that adequately represents reality.[70] While seemingly attractive, this notion fails when studies are inadequately powered, not all studies are published, and when researchers engage, willingly or naively, in problematic practices, commonly referred to as *p*-hacking.[25,30,70-72] When decisions researchers are forced to make in the process of collecting, analyzing, and reporting data are not specified in advance, but rather *on the fly,* researchers may be biased towards making these decisions to serve their chances of publication.[43,70] For example, in the hopes of results reaching statistical significance, researchers may choose to collect more data or attempt analyses with and without certain covariates or outliers. This differs from publication bias, which may also be due to people other than the author, such as editors, reviewers, or publishers. *p*-Hacking, greatly increases the likelihood of reporting false-positive and thus, nonexistent findings.[69] With this in mind, the notion of a protective ratio of true-negative to false-positive findings becomes implausible.[62]

As a consequence of *p*-hacking, the probability of false-positive findings increases relative to the probability of true-positives. This is problematic, as funding bodies and governmental agencies may make decisions based on published evidence that does not represent reality, that is, has no evidential value, and researchers may futilely attempt to investigate or reproduce nonexistent effects.[70] Thus, the presence of evidential value, and selective reporting regarding the effect of presurgical psychological variables in predicting outcomes from arthroplasty should be determined. Then, based on the presence of evidential value, further developments aimed at improving the efficacy of arthroplasty and reducing the considerable pain associated with OA[5] by improving patients' presurgical psychological profiles can be implemented.

P-Curve analysis[70] has emerged as a tool to establish the existing evidential value and identify instances of *P*-hacking. In *P*-curve analysis, the distribution of reported statistically significant *P* values allows researchers to determine whether selective reporting or true effects are present. In this way, *P*-curve analysis differs from meta-analyses.[71] Here, we use *P*-curve analysis to establish the presence or absence of evidential value and selective reporting using preregistered study criteria and methods in a sample of studies examining the effect of presurgical psychological predictors on outcomes following knee and hip arthroplastic surgery.

Methods

The study and *P* value selection criteria were finalized on November 7, 2018 and preregistered on www.aspredicted.org alongside the study's hypotheses and can be found here: https://aspredicted.org/394si.pdf.

Study Selection and Search Criteria

To be considered for inclusion in the *P*-curve analysis a study's hypothesis had to specifically state it was aimed at examining the predictive properties of at least one psychological variable measured prior to surgery on at least one postsurgical outcome. Presurgical psychological predictors of interest were limited to pain catastrophizing, fear of pain, mood, self-efficacy, kinesiophobia, depression, and anxiety; and postsurgical outcomes to pain intensity, consumption of analgesic medication, physical function, quality of life, and mood. The surgery of interest was replacement (arthroplasty) of the hip or knee. Several inclusion criteria were applied: 1) only peer-reviewed studies written in English were included; 2) participants must be generally healthy adults, undergoing any type of knee or hip replacement surgery and not suffering from any other physical disorders; 3) studies must be prospective in nature and evaluate the effect of one or multiple presurgical psychological predictors on one or multiple postsurgical outcomes; 4) predictors must be measured prior to surgery. Exclusion criteria were as follows: 1) studies examining a range of surgical interventions (ie, not arthroplasty of the hip or knee) and not differentiating the results of each group; 2) case studies; 3) studies examining the effects of interventions; 4) studies examining or not separating effects of participants undergoing unsuccessful surgeries. In the case of duplicate publications or publications that used the same set of patient data, only the most complete paper was included, or the first publication if patient numbers were identical. As only published papers were of interest, the gray literature was not searched.

Medline (PubMed) and PsycINFO (proquest) databases were searched using the terms: catastroph*, kinesiophob*, fear, mood, depress*, anxi*, self-efficacy, optimism, pessimism, arthropl*, knee replacement, hip replacement, TKJR, TKA, TKR, and THA. A total of 1,517 individual manuscripts were identified and subsequently reviewed independently by authors N.N. and S.C. Following this initial review, 46 full-texts were assessed for eligibility of which 20 manuscripts were excluded for at least one of the following reasons: nonsignificant findings (n = 6),[1,10,48,56,58,63] the analyses/results were not relevant to review hypotheses (n = 6),[6,9,20,35,42,90] and the critical test statistic was not reported, could not be computed based on reported data, and could not be obtained after contact with the author (n = 3)[3,18,86] (see Fig 1). The latter criterion included studies reporting *P*-value ranges (eg, $P < .05$) in the absence of data allowing the computation of critical test statistics or exact *P*-values. Inclusion of *P* value ranges would render the shape of the *P*-curve unreliable and such values were therefore excluded. In the case of multiple available *P* values, the values highest in the selection hierarchy were examined and if they were not suitable, the entire study was excluded.[70-72] Five other studies were excluded because they used the same

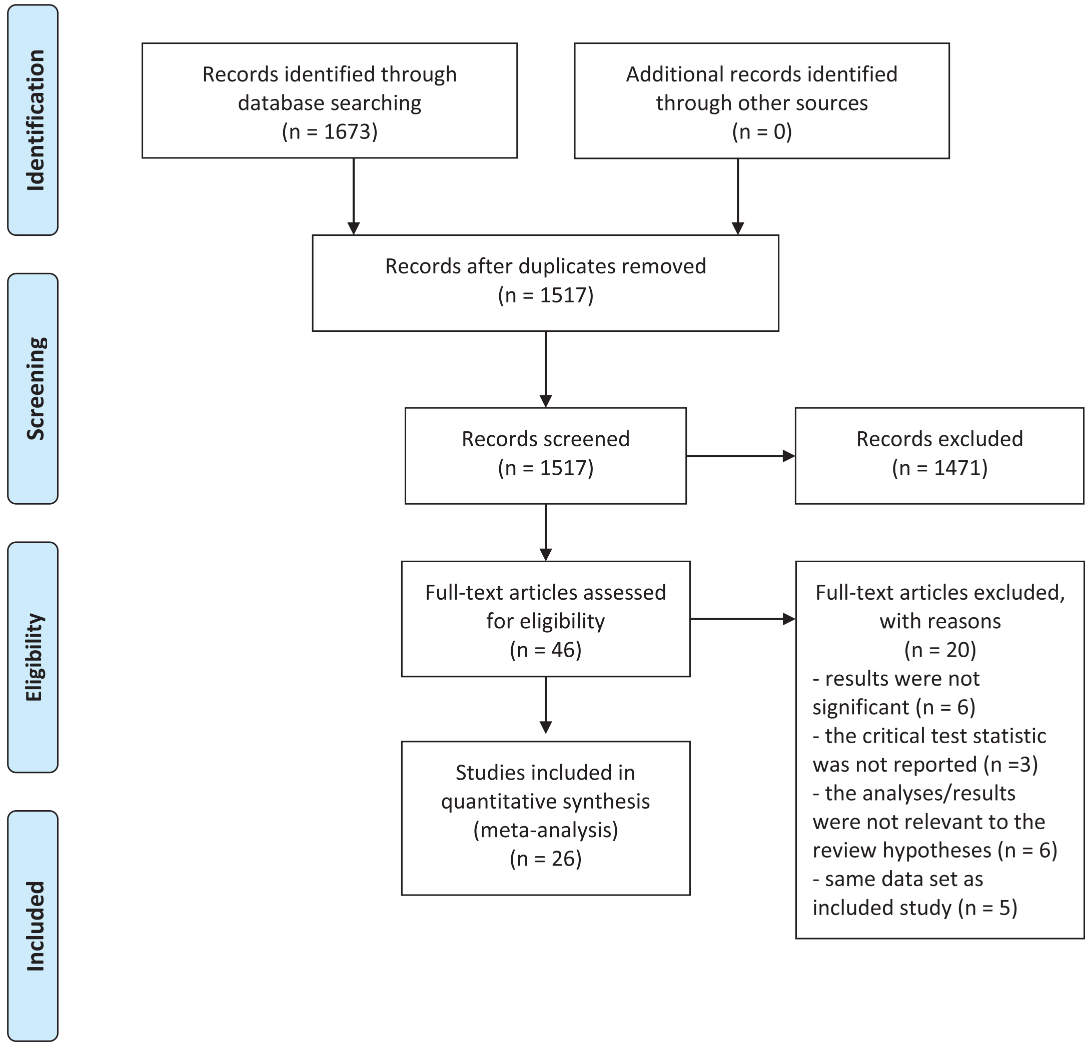

Figure 1. PRISMA 2009 flow diagram, overview of included and excluded studies.

dataset as another study by the same author that was included in the analysis, but was less complete (fewer participants),[73,75,89] or in case of identical patient numbers was published after the included study.[74,79] Thus, data from 26 studies were included in the analyses.

P *Value Selection*

P values associated with analyses that examine the predictive properties of psychological variables measured prior to surgery on postsurgical outcomes from relevant studies were selected. If more than one adequate *P* value was found in a study, the *P* value belonging to the analysis examining the postsurgical outcome closest to 6 months after surgery was selected. For example, in a case where there were 2 results examining whether pain catastrophizing predicts pain intensity at 1 month and 7 months after surgery, the *P*-value belonging to the analysis for 7 months postsurgery was selected. In the case of more than one relevant analysis (eg, correlations and linear regression or univariate and multivariate regressions) the following hierarchy for the selection of *P* values was applied: 1) regression – with covariates; 2) regression – without covariates; 3) other. In the case of "other", the first relevant *P*-value that was encountered in the first relevant table was used. In the case of odds ratios with categorical predictors, the first comparison reported in the corresponding table was used. All *P* values were recomputed, as per the recommendations by Simonsohn et al.[70]

During the *P* value extraction we followed the guidelines stipulated by,[70] which further outline when to include interaction effects, linear trends, or simple effects, based on the type of statistical test employed in the respective study. Following these guidelines, a *P*-curve disclosure table was completed (see Table 1), comprising of original text quoted from the included manuscripts delineating study design, key statistical results (including a quotation), type of surgery, study quality, and the quantitative results as included in the *P*-curve analysis as well as, where applicable, robustness results. Only significant results were recorded in the *P*-curve disclosure table.

P-*Curve Analyses*

We conducted a total of 9 *P*-curve analyses. In the case of multiple values extracted from the same study, the

Table 1. ***P*-curve Disclosure Table**

Original paper	Journal issue	Quoted text indicating prediction of interest	Study design	Type of surgery	Quoted text with statistical results	Predictor → Outcome	Results	Study quality
Banka et al, 2015[4]	The Musculoskeletal Journal of Hospital for Special Surgery, 11	The aims of this study were to identify whether patient-specific preoperative predictors including preoperative WOMAC pain score and visual analogue pain scale (VAS) catastrophizing pain scores were predictive of postoperative pain scores, referral to pain management and predictors of postoperative narcotic usage.	Prospective cohort study	TKA	A higher PCS was associated with a slight decrease in odds of postoperative opioid usage (OR = 0.96, 95% CI = .93−1.00) (Table 2).	Catastrophizing → Analgesic Consumption	Z = −2.21	14
Brander et al, 2007[11]	Clinical Orthopaedics and Related Research, 464 (464)	We previously reported preoperative depression, anxiety, and pain were associated with greater pain, more utilization of healthcare resources, and worse outcome 1 year after total knee arthroplasty. We asked whether these outcomes persisted over time and whether patients with unexplained heightened pain early after surgery were ultimately satisfied.	Prospective, longitudinal, single-cohort study	TKA	Preoperative pain and depressive symptoms predicted lower KSS at 5 years (*P* = .0003 and .0004, respectively) mainly as a consequence of worse function. Surprisingly, preoperative pain and depression did not predict a lower pain component but did predict a lower function component score at 5 years (*P* = .015 and .0004, respectively).	Depression → Function	t(79) = 3.688	13
Brembo et al, 2017[12]	Health and Quality of Life Outcomes, 68	The overall aim was to determine whether perceived social support and general self-efficacy contribute to the variability in short-term postoperative recovery in a sample of OA patients who have undergone THR.	Prospective study	THR	By contrast, self-efficacy and reliable alliance appeared to be significant predictors even after adjusting for age, number of comorbidities, and preoperative WOMAC (statistical results do not appear in text).	Self-efficacy → Function	t(165) = 2.070	13
Duivenvoorden et al, 2013[16]	Osteoarthritis and Cartilage, 21(12)	To examine the prevalence of anxiety and depressive symptoms in patients undergoing primary THA or TKA preoperatively and postoperatively, and the relationship between preoperative anxiety and depressive symptoms on PROs of THA and TKA.	Prospective study	THA TKA	In hip and knee patients, preoperative depressive symptoms predicted smaller changes in different HOOS or KOOS subscales and patients were less satisfied 12 months postoperatively. (statistical results do not appear in text)	Depression → Pain Anxiety → Pain Depression → QOL Anxiety → QOL Depression → Pain Anxiety → Pain Depression → QOL	t(145) = −3.497 t(145) = −2.714 t(145) = -2.756 t(145) = −3.18 t(133) = −2.799 t(133) = −2.111 t(133) = −2.041	13
Faller et al, 2003[19]	General Hospital Psychiatry, 25	The aim of this study was to determine whether patients who were psychologically distressed at baseline had worse outcomes regarding physical role limitations during household and work activities at both 3 and 12 months after total knee arthroplasty (TKA).	Prospective study	TKA	When predicting the 3-months Function index, the beta weight of baseline psychological distress was .25 (*P* = .032), after adjusting for the baseline Function index beta = .58, *P* = < .001).	Anxiety → Function Depression → Function	t(57) = 2.185 t(57) = 2.185	12
Hanusch et al, 2014[29]	Bone and Joint Journal, 96 B (2)	This cohort study investigated the influence of psychological factors, including perception of illness, anxiety and depression on recovery and functional outcome after total knee replacement surgery.	Prospective cohort study	TKA	The HADS variable depression was also correlated with OKS at 6 weeks (*P* = .003) and entered into a separate multiple regression analysis.	Depression → Function	t(92) = 1.986	13
Hirschmann et al, 2013[33]	Knee Surgery, Sports Traumatology, Arthroscopy, 21(10)	The purpose was to investigate if preoperative psychological factors influence the subjective and objective outcomes 6 weeks, 4 months and 1 year after TKA. Our hypothesis was that there is a significant influence of psychological factors on clinical outcome scores before and after TKA.	Prospective, longitudinal, single-cohort study	TKA	More depressed patients showed higher postoperative WOMAC scores. Patients with higher trait anxiety indexes had higher WOMAC and lower KSS scores after the operation (statistical results do not appear in text)	Depression → Pain Anxiety → Pain Depression → Function Anxiety → Function	r(102) = 0.29 r(102) = 0.25 r(102) = 0.37 r(102) = 0.25	16
Judge et al, 2012[37]	Rheumatology, 12	The primary aim of this study was to identify whether patients' pre-operative characteristics can predict patient- reported outcomes [as measured by the Oxford Knee Score (OKS)] 6 months after surgery in a large prospective cohort of patients receiving primary TKR in the UK National Health Service (NHS).	Prospective longitudinal cohort study	TKR	Specifically for pain, patients with a diagnosis of RA had better outcomes compared with those with primary OA, and people with anxiety/depression had worse outcomes. (Moderately depressed/anxious (reference Not anxious/depressed) → Pain: OR = .67, 95% CI = .54−.84); (Moderately depressed/anxious (reference Not anxious/depressed) → Function: OR = .77, 95% CI = .61, .97)	Depression → Pain Depression → Function Anxiety → Pain Anxiety → Function	Z = −3.553 Z = −2.209 Z = -3.639 Z = −2. 209	12
Kagan et al, 2008[38]	Journal of Clinical Nursing, 17(5)	This study examined the effect of preoperative anxiety and uncertainty on short−term physical and mental recovery after elective arthroplasty.	Quazi-−experimental study	TKA/THA	Both preoperative anxiety and uncertainty were negatively related to all postoperative recovery variables except subjective readiness to be discharged. (statistical results do not appear in text)	Anxiety → QOL (wellbeing)	t(84) = 2.66	15
Langlois et al, 2015[44]	Knee Surgery, Sports Traumatology, Arthroscopy, 23(6)	This study aims to define the determinants affecting post-operative midterm active flexion according to a specific cruciate-sacrificing prosthesis, the rotating concave−convex (ROCC®) TKA.	Prospective study	TKA	Depression was also found to be significantly correlated with post-AF (coefficient −4.4 ± 1.2, *P* < .001).	Depression → Function	t(456) = −2.587	13

(*continued on next page*)

Table 1. Continued

Original paper	Journal issue	Quoted text indicating prediction of interest	Study design	Type of surgery	Quoted text with statistical results	Predictor → Outcome	Results	Study quality
Lindner et al, 2018[46]	BMC Musculoskeletal Disorders, 19(1)	As findings regarding predictors for good outcome after total joint arthroplasty are highly inconsistent, aim of this study was to investigate the influence of the psychosocial variables sense of coherence and social support as well as mental distress on physical outcome after surgery.	Prospective study	THA/TKA (significant results for THA only)	In THA, 12-weeks WOMAC scores were predicted by baseline measures of psychosocial aspects (anxiety, sense of coherence, social support). (statistical results do not appear in text)	Anxiety → Pain Anxiety → Function	t(38) = 3.11 t(38) = 3.69	14
Lopez-Olivo et al., 2011[47]	Clinical and epidemiological research, 70(10)	The objective of this study was to identify potential psychosocial and educational barriers to surgical success following knee replacement.	Prospective cohort study	TKR	Worse WOMAC function scores were associated with less tangible support, depression and decreased problem-solving coping (R2 = .19). (statistical results do not appear in text)	Depression → Function	t(225) = 2.343	15
McHugh et al, 2013[50]	Bone Joint Research, 2(11)	The overall aim of this study was to investigate the biomedical and psychosocial outcomes following THR in patients with OA and to determine which predictors are associated with better outcomes of recovery from THR.	Prospective study	THR	In addition to the expected relationship with the preoperative Total Physical Score ($P < .001$), change in Total Physical Score at 6 months was significantly and negatively associated with baseline HADS anxiety and depression scores and WOMAC pain score at baseline ($P = .034$, $P = .001$ and $P < .001$, respectively). (statistical results do not appear in text)	Anxiety → Function Depression → Function	t(183) = 2.136 t(183) = 3.344	15
Noiseux et al, 2014[52]	The Journal of Arthroplasty, 29(7)	Do high patient scores on scales of psychological state prior to TKA, such as depression, anxiety and pain catastrophizing, predict pain intensity ratings after total knee?	Prospective cohort study	TKA	Anxiety was the other variable found to be significant in the postoperative multifactor analysis, with an odds ratio of 1.40.	Anxiety → Pain	Z= 2.6120	12
Pinto et al., 2015[53]	Annals of Behavioral Medicine, 49(3)	The aims of this study are to identify psychological predictors of post-surgical pain following abdominal hysterectomy (AH) and major joint arthroplasty (MJA) and to investigate differential predictors by type of surgery.	Prospective cohort study	TKA/THA	Optimism was added as the last block, constituting a significant predictor ($t(103) = -3.461$, $\beta = -.297$, $P = .001$).	Optimism → Pain	t(114) = −3.461	14
Pinto et al, 2013[55]	Journal of Pain, 14(5)	This study aims to examine the joint role of demographic, clinical, and psychological variables as predictors of acute postsurgical pain and anxiety in patients undergoing total knee arthroplasty and total hip arthroplasty	Prospective cohort study	TKA/THA	Optimism was the only significant predictor of pain in the final regression model (b = .24, $P = .008$).	Optimism → Pain	t(119) = −2.716	14
Pinto et al, 2017[54]	Journal of Pain Research, 10	This study aims to compare acute postsurgical pain intensity, and its potential predictors, between two types of major joint arthroplasties: THA and TKA.	Prospective longitudinal cohort study	TKA/THA (significant results for TKA only)	In the final model, optimism was the only significant predictor of pain ($t[51] = -2.518$, $\beta = -.339$, $P = .015$).	Optimism → Pain	t(53) = −2.518	13
Riddle et al, 2010[60]	Clinical Orthopaedics and Related Research, 468(3)	We therefore asked whether either psychologic disorders or pain-related beliefs could predict either pain or physical function outcome after knee arthroplasty.	Prospective longitudinal cohort study	TKA	Pain intensity: For WOMAC pain, only the dichotomized PCS score (odds ratio [OR], 2.67; 95% confidence interval [CI], 1.2−6.1) predicted improvement by the less than 50% poor outcome criterion after adjustment for potential confounders. F = 5.47, $P = .02$.	Catastrophizing → Pain	F(1,134) = 5.47	14
Rolfson et al, 2009[61]	The Journal of Bone and Joint Surgery, 91(2)	In this study we used subjects in the Swedish registry to examine the hypothesis that anxiety/ depression (one of the five dimensions of the EQ-5D) is a significant variable in predicting satisfaction and pain relief after THR.	Prospective longitudinal cohort study	THA	Adjusting for all dimensions of EQ-5D preoperatively, Charnley category, age and gender, multivariate linear regression analysis showed that the degree of pain relief and satisfaction 1 year after surgery were related to preoperative anxiety/depression in the fifth EQ-5D dimension and reduction of the Charnley category. (statistical results do not appear in text)	Anxiety → Pain Depression → Pain	t(6149) = −5.166 t	
	(6149) = −5.166	13						
Salmon et al, 2001[64]	Journal of Behavioral Medicine, 24(5)	The present study therefore examined the relationship of perioperative emotional state to functional recovery from hip arthroplasty, using reliable and validated measures of postoperative recovery which were also used to control for preoperative function.	Prospective longitudinal cohort study	THA	In the analysis of WOMAC at 6 months, preoperative WOMAC was again significant. From the POMS variables entered in the second block, preoperative fatigue was significant beta .25, $P < .01$, b = 83, (CI .20, 1.47).	Mood → Function	t(98) = 2.594	14

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Table 1. Continued

Original paper	Journal issue	Quoted text indicating prediction of interest	Study design	Type of surgery	Quoted text with statistical results	Predictor → Outcome	Results	Study quality
Sanchez-Santos et al, 2018[65]	Scientific Reports, 8(1)	Therefore, as an example application of clinical prediction model, we developed and externally validated a simple prediction model for improvement in pain and function 12 months after TKR using data from the Knee Arthroplasty Trial (KAT) 20,21 (development dataset) and the Clinical Outcomes in Arthroplasty study (COASt) (validation dataset).	Prospective study	TKA	Worse preoperative OKS, self-reported anxiety/depression, presence of ASA grade 3/4 (compared to fit and healthy), presence of other conditions affecting mobility and previous knee arthroscopy were strongly associated with worse outcome. Beta −1.6 (CI = −2.5 to −0.6), *P* = .001.	Depression → Pain Depression → Function Anxiety → Pain Anxiety → Function	t(1636) = 3.29 t(1636) = 3.29 t(1636) = 3.29 t(1636) = 3.29	13
Singh et al, 2012[76]	Arthritis Research & Therapy, 14	We hypothesized that patient demographics and comorbidities will be associated with the use of pain medications after TKA. Specifically, we assessed whether female gender, younger age, higher BMI, pre-operative medical comorbidities, depression and anxiety, were associated with use of NSAIDs and opioid pain medications at 2 and 5 years after TKA.	Prospective longitudinal cohort study	TKA	Presence of depression increased the odds of NSAID use by 1.4, compared to those without depression. (Depression (reference no depression) → Analgesic consumption: OR = 1.39, 95% CI = 1.04−1.85, *P* = .03)	Depression → Analgesic consumption	Z = 2.241	12
Sullivan et al, 2009[80]	PAIN, 143	In the present study, patients scheduled for TKA were assessed one week prior to surgery and then again 6-weeks post-surgery. Analyses examined the value of pre-surgical measures of pain catastrophizing, pain-related fears of movement and depressive symptoms in the prediction of postsurgical pain severity and physical function.	Prospective longitudinal cohort study	TKA	Pre-surgical scores on measures of pain catastrophizing, pain-related fears, and depression were significantly correlated with postsurgical measures of pain and function.	Catastrophizing → Pain Anxiety → Function	Z= 4.1531 Z= 3.3627	12
Thomazeau et al, 2016[84]	European Journal of Pain (United Kingdom), 20(5)	In this prospective observational cohort study, we aimed to identify the determinants of acute postoperative pain intensity at rest and post-operative opioid requirement in the context of multimodal analgesia, in patients undergoing knee arthroplasty.	Prospective longitudinal cohort study	TKA	Mean postoperative opioid requirement (*P* < .001), HAD-A score (*P* = .001), DN4 score (*P* = .030) and preoperative pain at rest (*P* = .047) were independently positively associated with mean postoperative pain at rest.	Anxiety → Pain	t(94) = 3.52	13
Wylde et al, 2012[88]	Musculoskeletal Care, 10(2)	The purpose of this study was to determine if self-efficacy was a significant and independent preoperative predictor of patient-reported pain and function at 1 year after TKR.	Prospective longitudinal cohort study	TKA	In this model, self-efficacy contributed significantly to explaining the variance in postoperative knee function, with worst scores predicting greater functional limitations after TKR (*P* = .024). (unstandardized regression coefficient: −.256).	Anxiety → Pain Anxiety → Function Self-Efficacy → Function	t(211) = 2.678 t(211) = 2.307 t(211) = 2.274	12
Yakobov et al, 2018[91]	Health and Quality of Life Outcomes, 16(1)	The purpose of the present study was to determine the value of presurgical pain catastrophizing in predicting HRQoL judgments after TKA	Prospective longitudinal cohort study	TKA	Examination of the standardized beta weights from the final regression equation indicated that only baseline SF-12 PCS (β = .37, *P* < .001) and pain catastrophizing (β = −.35, *P* < .001) contributed significant unique variance to the prediction of postsurgical SF-12 PCS.	Catastrophizing → Pain	t(115) = 3.377	12

Abbreviations: THA, Total hip arthroplasty; TKA, Total knee arthroplasty; THR, Total hip replacement; TKR, Total knee replacement; QOL, Quality of life; study quality was assessed using the Methodological Index for Non-Randomized Studies (MINORS), results out of 16; All values are limited to 3dp.

value mentioned first in the manuscript was selected. We ran additional *P*-curve analyses including the omitted values to examine the robustness of the findings. The first analysis comprised of data from all 26 included studies (27 *P* values) and examined the evidential value of presurgical psychological predictors on function, well-being, analgesic consumption, and reported pain intensity following surgery. Some sets of studies were too small for individual *P*-curve analyses, that is, catastrophizing on function, self-efficacy on function, and anxiety on quality of life, depression on analgesic consumption, and pain catastrophizing on analgesic consumption, each set comprising of no more than 2 test statistics. These studies were, however, included in the overall analyses of psychological predictors on function and pain intensity where applicable. The remaining 8 analyses examined the evidential value underlying the following relationships between presurgical psychological factors and postsurgical outcomes: 2) presurgical psychological factors on function (n = 14), 3) presurgical psychological factors on pain intensity (n = 16), 4) depression on function (n = 9), 5) depression on pain intensity (n = 6), 6) anxiety on pain intensity (n = 10), 7) anxiety on function (n = 8), pain catastrophizing on pain intensity (n= 3), and 9) optimism on pain intensity (n = 3; see Table 1 for an overview and study details).

Computing the P-Curves

A detailed description of *P*-curve analysis can be found here.[70-72] To conduct the *P*-curve analyses, we used the online *P*-curve app (version 4.06, www.p-curve.com/app4/). Test statistics, rather than *P*-values, were entered directly into the application alongside degrees of freedom (eg, t(211) = 2.274). *p*-curve analysis examines the distribution of significant reported *P* values ($P <$ .05) and effectively tests whether 1) there is evidential value (*P*-curve is significantly right-skewed) or 2) the studies show inadequate, if any, evidential value (*P*-curve is found to be flatter compared to a *P*-curve comprised of studies powered at 33%). Evidential value signifies whether reported significant results per se constitute evidence for the experimental hypothesis. In the case of a true effect (evidential value is present), the distribution of *P*-values is right-skewed, as it is more likely to contain lower *P*-values (eg, .01) rather than high *P*-values (eg, 0.04). For a set of studies with no or inadequate evidential value the distribution of *P*-values is expected to be uniform, while intense *P*-hacking results in a left-skewed distribution of *P* values (ie, more high than low *P*-values).

The nature of the distribution is quantified by the application through 2 continuous tests, the half (includes only values $P < .025$) and full *P*-curve (includes all *P* values) tests, as well as a binomial test. In the case of the continuous tests, the likelihood of observing a *P* value at least as extreme as the one entered (*P* value) is calculated in case there is no effect expected (test for right skew) and in case of the studies being powered at an average 33% (test for inadequacy of evidential value). Next, using Stouffer's method, the obtained results are aggregated. The binomial test involves calculating the proportion of *P* values above and below .025 and comparing this proportion against the expected proportion in case there is no effect (50%; test for right skew) or if the studies have 1/3 power (roughly 71% depending on df of entered test statistics; test for inadequacy of evidential value).

Presence of evidential value is indicated when either 1) the half *P*-curve test is right skewed ($P < .05$) or 2) the half *P*-curve test as well as the full *P*-curve test are right-skewed ($P < .10$). Next, the application tests whether evidential value is inadequate or absent. To this end, the *P*-curve's right skew is compared to that of a *P*-curve that is powered at 33%. Again, 2 conditions may be satisfied to indicate the inadequacy of evidential value for a real effect: 1) the full *P*-curve 33% power test is $P < .05$ or 2) the binomial as well as the continuous half *P*-curve 33% power test is significant at $P < .10$. Furthermore, while not formally tested by the application, a *P*-curve that shows no significant right skew and shows a left skew (more *P* values above .25 than below) may indicate selective reporting within the examined studies. Finally, the application calculates the average power, underlying the statistical tests included in the analysis.

Secondary Analyses

According to Simonsohn et al,[70] a *P*-curve analysis should be conducted twice if there is some ambiguity as to whether a specific study or value should be included. One study, Faller et al,[19] used presurgical scores on the Hospital Anxiety and Depression scale (HADS) to predict function postsurgery, but did not present separate results for depression and anxiety. Data from this study are relevant for analyses 4 and 7, which were therefore performed twice, once with and once without the data from Faller et al.[19] The findings presented below include the results from Faller et al.[19] The pattern of results did not differ between analyses including and excluding the results from Faller et al.[19] Similarly, the study by Judge et al[37] used the anxiety/depression subscale of the EQ-5D to predict pain and function postsurgery, relevant for analyses 4 through 7, which were therefore conducted twice. The findings presented below include the results from Judge et al[37] and there were no differences in the results between their in- or exclusion.

Study Quality Assessment

The Methodological Index for Non-Randomized Studies (MINORS)[77] was used to assess study quality. This tool has been found to be excellent in rating study quality for nonrandomized interventional studies,[92] such as those involving surgical interventions. The MINORS comprises of 8 methodological items for nonrandomized studies that are scored as "0" for "not reported," "1" for "reported but inadequate," and "2" for "reported and adequate," hence study quality scores range from 0 to 16. Study quality assessments were completed independently by N.N. and S.C. for the final 26 studies. Agreement on the outcome was assessed through intraclass correlation. Differences in study quality assessments were resolved through discussion.

Results

Main P-Curve Results

Nine *P*-curve analyses were completed following the methods outlined above. For each analysis, the evidential value of the included *P* values was first examined using the right-skew test. Next, to assess whether the *P* values' evidential value was inadequate the 33% power test was used. An estimate of the average statistical power underlying the studies from which the *P*-values stem is finally presented including 90% confidence interval (CIs).

Pre-surgical Psychological Factors on Postsurgical Outcomes

A *P*-curve analysis was computed with data from all 26 studies to examine the evidential value of presurgical psychological predictors on function, wellbeing, analgesic consumption, and reported pain after surgery. The *P*-curve was significantly right skewed (full *P*-curve: Z = −5.01, *P*< .0001; half *P*-curve: Z = −4.99, *P* < .0001), indicating that the *p*-values included in the analysis cumulatively contain evidential value (see Fig 2A). This was further supported by the absence of a left skew (Binomial test: *P* = .7018; Continuous tests: full *P*-curve: Z = 1.43, *P* = .9232; half *P*-curve: Z = 6.25, *P* > .9999), indicating that evidential value is not inadequate or absent. Therefore, there is no indication of ambitious *p*-hacking across predictors and outcomes. The statistical power of this analysis was estimated at 53% (90% CI = 31−72%). Given that there were multiple values extracted from the same study in this analysis, the values mentioned first in the respective manuscripts were selected. We ran additional *P*-curve analyses including the omitted values to examine the robustness of the findings and found no differences in the pattern of results.

Presurgical Psychological Factors on Function

P-values from 14 studies were included in the examination of the evidential value underlying pre-surgical psychological predictors on function. Results indicate that the *P* values included in this analysis contain evidential value, as supported by a significant right skew (full *P*-curve: Z = −2.06, *P* = .0195; half *P*-curve: Z = −2.89, *P* = .0019; see Fig 2B). Similarly, the absence of a left skew indicates that evidential value is not inadequate or absent (Binomial test: *P* = .3804; Continuous tests: full *P*-curve: Z = −.33, *P* = .371; half *P*-curve: Z = 3.94, *P* > .9999), suggesting that there is no evidence of ambitious *p*-hacking in the investigation of presurgical psychological factors on post-surgical function overall. The statistical power of this analysis was estimated at 27% (90% CI = 7−60%). We ran additional *P*-curve analyses including the omitted values to examine the robustness of the findings where there were multiple values extracted from the same study in this analysis and found no difference in the pattern of results.

Presurgical Psychological Factors on Pain Intensity

To investigate the evidential value of presurgical predictive factors on pain intensity, *P*-values from 16 studies were included in the analysis. The results showed a significant right skew (full *P*-curve: Z = −6.88, *P* < .0001; half *P*-curve: Z = −5.1, *P* < .0001; see Fig 2C), indicating evidential value. This was further supported by the absence of a left skew (Binomial test: *P* > .9999; Continuous tests: full *P*-curve: Z = 3.72, *P* = .9999; half *P*-curve: Z = 5.75, *P* > .9999), suggesting that evidential value is not inadequate or absent. Therefore, there is no indication of ambitious *p*-hacking across the examination of presurgical psychological factors on postsurgical pain. Finally, the power of the tests included in the analysis was estimated at 83% (90% CI = 65−93%). Given that there were multiple values extracted from the same study in this analysis, the values mentioned first in the respective manuscripts were selected. We ran additional

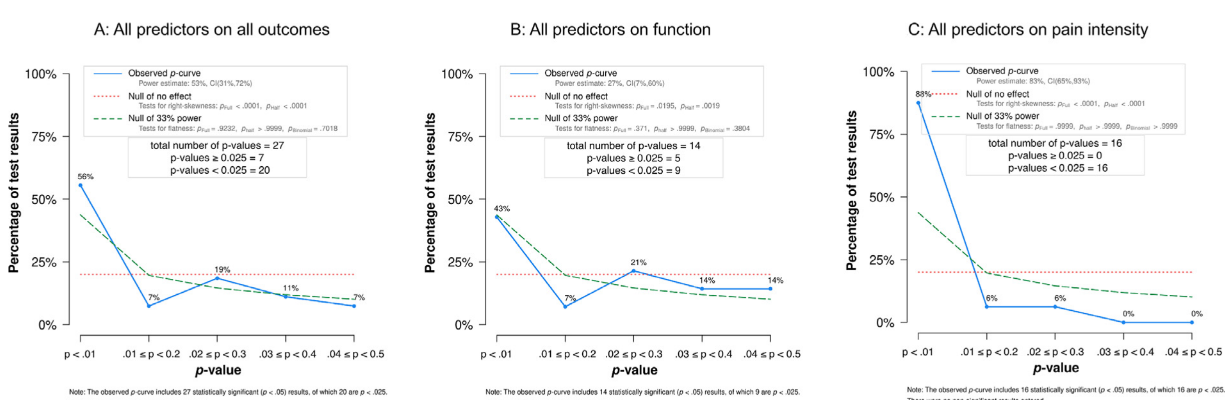

Figure 2. *P*-Curve analyses for the effects of all pre-surgical psychological predictor variables on all outcomes, pain intensity and function. All *P*-curve analyses indicated the existence of evidential value. Values listed at .01 represent the number of *P*-values smaller than .01. Values listed at .02 represent the number of *P*-values between .01 and .02, etc.

P-curve analyses including the omitted values to examine the robustness of the findings and found no differences in the pattern of results.

Depression on Function

To examine the evidential value behind depression predicting function following arthroplasty, nine *P*-values were identified and included in the analysis. Results indicate that the *P* values included in the analysis cumulatively contain evidential value as indicated by a significant right skew of the *P*-curve (full *P*-curve: Z = −1.93, *P* = .0266; half *P*-curve: Z = −3.12, *P* = .0009; see Fig 3A). This finding is supported by the absence of a left skew, which indicates that the evidential value is not inadequate or absent (Binomial test: *P* = .507; Continuous tests: full *P*-curve: Z = .05, *P* = .4788; half *P*-curve: Z = 3.56, *P* = .9998). Therefore, there is no indication of ambitious *p*-hacking. Finally, power of the included tests was estimated at 32% (90% CI = 7−70%). Removal of the test statistics extracted from Faller et al[19] and Judge et al[37] did not meaningfully alter the results.

Depression on Pain Intensity

After entering 6 significant test statistics into the application, the results indicated that there is evidential value underlying the effect of presurgical depression levels on postsurgical pain intensity (full *P*-curve: Z = −5.68, *P* < .0001; half *P*-curve: Z = −4.92, *P* < .0001, see Fig 3B). There was also no evidence indicative of a left skew in the distribution according to the Binomial test (*P* > .999) and continuous z-tests (full *P*-curve: Z = 3.55, *P* = .9998; half *P*-curve: Z = 4.53 *P* > .9999), suggesting the absence of intense *p*-hacking and no lacking of evidential value. Finally, power of the included tests was estimated at 93% (90% CI = 75−99%). Removal of the test statistics extracted from Judge et al[37] did not meaningfully alter the results.

Anxiety on Function

To test the evidential value underlying the effect of anxiety in predicting postsurgical function we included 8 *P* values in the analysis. The analysis suggests that there is evidential value underlying the association between presurgical anxiety and postsurgical function (full *P*-curve: Z = −2.25, *P*=.0122; half *P*-curve: Z = −2.03, *P* = .021; see Fig 4A). Evidential value is neither inadequate nor absent, and so there is no evidence of intense *p*-hacking an indicated by an absence of a left skew (Binomial test: *P* = .4207; Continuous tests: full *P*-curve: Z = 0.38, *P*=.6468; half *P*-curve: Z = 2.84, *P* = .9977). Finally, the power of the tests included in the analysis was estimated at 43% (90% CI = 9−79%). Removal of the test statistics extracted from Faller et al[19] Judge et al[37] did not meaningfully alter the results.

Anxiety on Pain Intensity

Ten statistically significant estimates were included in the analysis examining the evidential value underlying the effect of anxiety on postsurgical pain intensity. The results indicate that there is evidential value underlying the findings (full *P*-curve: Z = −4.97, *P* < .0001; half *p*-curve: Z = −4.25, *P* < .0001; see Fig 4B). Furthermore, there was no evidence of a left skew in the distribution according to the Binomial test (*P* = .9668) and continuous z-tests (full *P*-curve: Z = 2.54, *P* = .9944; half *P*-curve: Z = 4.51, *P* > .9999), suggesting the absence of intense *p*-hacking and no lacking of evidential value. Finally, power of the included tests was estimated at 79% (90% CI - 51−93%). Removal of the test statistics extracted from Judge et al[37] did not meaningfully alter the results.

Pain Catastrophizing on Pain Intensity

Three *P*- values were examined for the presence of evidential value underlying the effect of pain catastrophizing predicting postsurgical pain intensity. The analysis revealed that there is evidential value

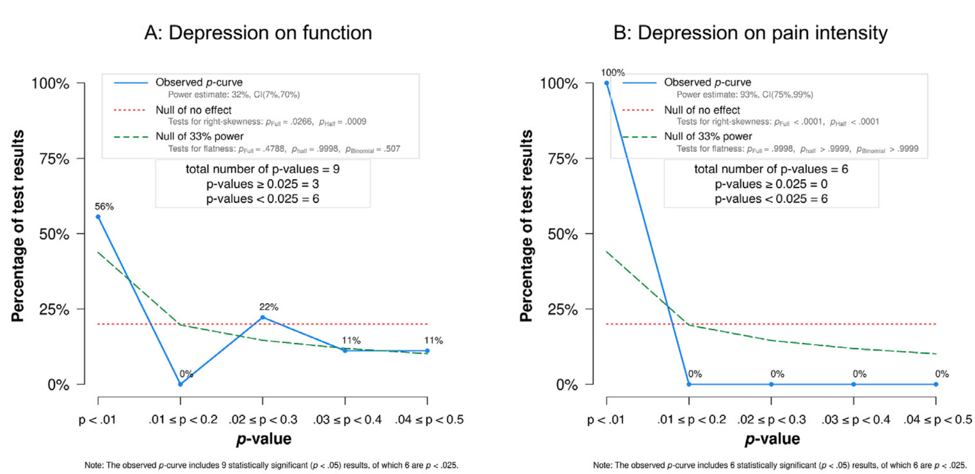

Figure 3. *P*-Curve analyses for the effects of depression on function and pain intensity. Both *P*-curve analyses indicated the existence of evidential value. Values listed at .01 represent the number of *P*-values smaller than .01. Values listed at .02 represent the number of *P*-values between .01 and .02, etc.

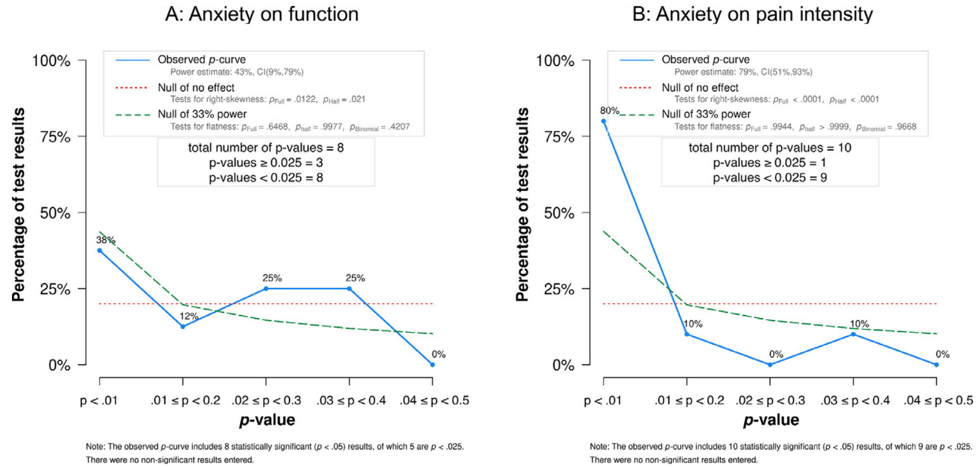

Figure 4. *P*-Curve analyses for the effects of anxiety on function and pain intensity. Both *P*-curve analyses indicated the existence of evidential value. Values listed at .01 represent the number of *P*-values smaller than .01. Values listed at .02 represent the number of *P*-values between .01 and .02, etc.

underlying the relationship between presurgical pain catastrophizing and postsurgical pain intensity (full *p*-curve: Z = −3.16, *P* = .0008; half *P*-curve: Z = −2.19, *P* = .0143; see Fig 5). Evidential value is neither inadequate nor absent, and so there is no evidence of intense *p*-hacking an indicated by an absence of a left skew (Binomial test: *P* > .9999; Continuous tests: full *P*-curve: Z = 1.77, *P* = .9617; half *P*-curve: Z = 2.68, *P* = .9963). Finally, the power of the tests included in the analysis was estimated at 85% (90% CI = 38–98%).

Optimism on Pain Intensity

Three *P* values were included in the examination of the evidential value underlying the predictive properties of optimism on pain intensity. All *P* values stem from results indicating a negative relationship between optimism and pain intensity. The conditions for the presence of evidential value are not met (full *P*-curve: Z = −2.15, *P* = .0157; half *P*-curve: Z = −1.24, *P* = .1071, see Fig 6). Nevertheless, there is also no indication of a left skew, suggesting that evidential value is neither inadequate nor absent and there is no evidence of intense *p*-hacking (Binomial test: *P* > .9999; Continuous tests: full *P*-curve: Z = 0.90, *P* = .8151; half *P*-curve: Z = 1.91, *P* = .9719). Finally, the power of the tests included in the analysis was estimated at 66% (90% CI = 11–95%).

Study Quality

Study quality ranged from 12 to 16 and was overall adequate. Ratings for the individual studies are shown in Table 1 and there was a high level of agreement between raters (intraclass coefficient = .94).

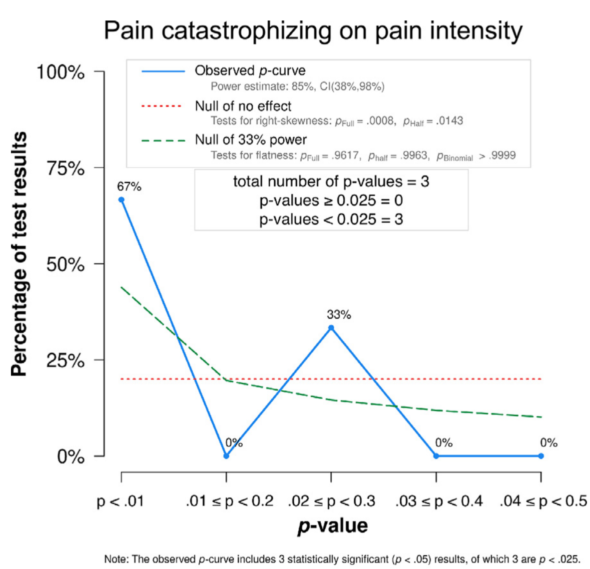

Figure 5. *P*-Curve analysis for the effects of pain catastrophizing on pain intensity. The *P*-curve analysis indicated the existence of evidential value. Values listed at .01 represent the number of *P*-values smaller than .01. Values listed at .02 represent the number of *P*-values between .01 and .02, etc.

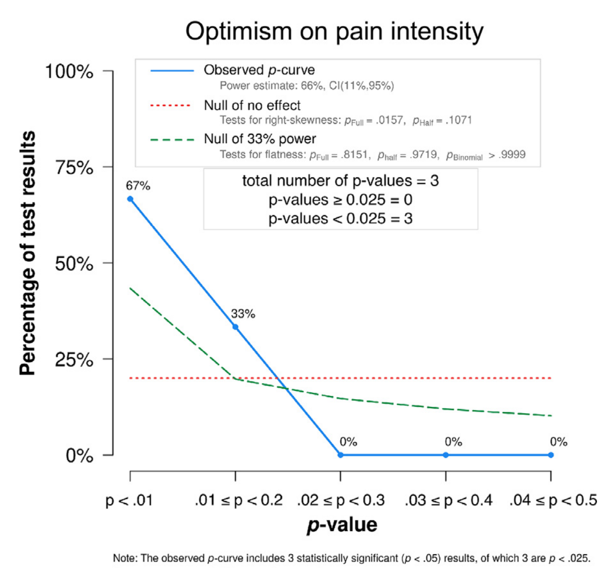

Figure 6. *P*-Curve analysis for the effects of optimism on pain intensity. The *P*-curve analysis indicated that the presence of evidential value could neither be confirmed nor rejected. Values listed at .01 represent the number of *P*-values smaller than .01. Values listed at .02 represent the number of *P*-values between .01 and .02, etc.

Discussion

In this study, we found support for the presence of evidential value for all but one (optimism on pain intensity) of the examined sets of studies investigating the effect of presurgical psychological predictors on outcomes following knee and hip arthroplasty. This suggests that the reported significant results in themselves constitute evidence for the experimental hypotheses. The analyses indicated the presence of evidential value for the effect of depression on pain intensity and function, anxiety on pain intensity and function, pain catastrophizing on pain intensity, as well as the combined effects of all predictors on all outcomes, and all predictors on pain intensity and function respectively. In particular, our findings suggest that presurgical depression and anxiety are robust predictors of higher postsurgical pain and poor function. The findings highlight the importance of patients' psychological profiles in determining surgical success. Furthermore, the notion that selective reporting may be a likely explanation for these sets of statistically significant findings can be ruled out, as there were no signs of intense *p*-hacking underlying the reported effects for all examined sets of studies.

Depression and anxiety may negatively influence patients' motivation to engage in rehabilitation exercises and to overcome challenges in the recovery process and resume recreational, household, or social activities following surgery.[26,79] This inactivity may lead to deconditioning, further arthritic degeneration and promote deteriorations in mood and health status. It has also been suggested that anxious patients tend to opt for surgery at a later time, when symptoms are more severe,[8] increasing the likelihood of poor outcomes.

Psychosocial predictors may affect neurophysiological processes involved in pain modulation.[14,24] For example, pain catastrophizing, depression, and anxiety have been linked with an increased sensitivity to pain.[31,34,57,67,81] The resultant repeated painful stimulation may promote sensitization in the central nervous system by enacting neuroplastic changes in the spinal cord.[27] Thus, these patients may find using pain medication to manage postsurgical pain less effective and repeated stimulations, such as during rehabilitation exercises, are experienced as increasingly painful, which makes patients less likely to engage in such exercises and remain sedentary. Furthermore, patients with certain psychological profiles, such as high levels of pain catastrophizing, anxiety, and depression may interpret surgery and repeated painful stimulations as more stressful.[21,23,28,34,39,83] The subsequent stress response may hamper the healing process by promoting glucocorticoid release[66] and suppressing lymphocyte circulation in the blood.[15] Pain following surgery is inevitable, not just during rehabilitation exercises. This pain may elicit a greater stress response that prolongs the healing process and leads to a higher frequency of painful experiences following surgery.

While the set of *P* values pertaining to the link between presurgical optimism and postsurgical pain intensity was right-skewed, neither condition necessary to indicate evidential value was met. Conversely, evidential value was also not inadequate, which suggests that the set of results are unlikely to be due to selective reporting. This does not imply that there is no association between presurgical optimism and postsurgical pain intensity, but rather that no definitive statement regarding the presence and magnitude of the evidential value can be made for the selected set of studies. The set of studies subject to this analysis included three studies from the same primary author.[53-55] Reasons for the inconclusiveness of the results may be rooted in the low number of studies and observations within studies. Thus, these results should be viewed with caution. Furthermore, the nature of the results may stem from combining results for total hip arthroplasty (THA) and total knee arthroplasty (TKA). One study[54] reported results separately for THA and TKA, while two[53,55] did not differentiate between hip and knee arthroplasty. In the case of THA, optimism did not predict outcomes following surgery,[54] and so it is possible that the link between optimism and pain intensity varies between knee and hip arthroplasty. Results combining both sites may therefore lead to higher *P* values, obscuring the true evidential value. Future studies should further investigate the presence of surgery-specific effects. Lastly, optimism was quantified as a trait in these investigations and may be more predictive when operationalized as outcome expectancy specific to surgery.[49]

p-Curve analysis allows the distinction between sets of findings that are likely and unlikely to suffer from selective reporting.[70] Therefore, the absence of evidential value of a specific set of results does not imply that the theory proposed to underlie the significant results is wrong. *P*-Curve examines the reported data and not the theory and therefore itself is susceptible to noise, sample sizes, and other biases.[70] The levels of power estimated for the sets of studies suggest that the majority of studies are not adequately powered. In particular the main *P*-curve analysis revealed a power estimate of 53% (90% CI = 31−72%). Low to medium levels of statistical power may help explain the presence of null results in the literature. Similarly, it should be noted that only published studies were examined, potential high-quality studies were possibly excluded due not reporting relevant test statistics, and the search was limited to 2 data bases. Thus, publication bias may have influenced the nature of the findings. Most of the included studies examined links of anxiety and depression with pain and function. Only a single eligible study reported test statistics for a quality of life outcome and few others for the links of pain catastrophizing and optimism with outcomes. While caution is warranted when interpreting our study's findings, we used a disclosure table and preregistered the study details to limit the influence of biases. Differences in methodology, timing of assessments, and assessment tools may also have affected results. For example, timing of postsurgical assessment ranged from 48 hours to up to 5 years. Assessments also varied; for depression, among others, the HADS and the EQ-D5 were used. Furthermore, current reporting practices precluded the inclusion of several relevant studies, as essential test statistics were not provided, tis, hat no exact *P* values or associated test statistics. This reiterates the importance of conducting *P*-curve analyses, as such practices may be a naÿve form of selective reporting. We recommend that authors aim to disclose exact *P* values and all relevant test statistics in the future in order to ameliorate this issue.

The presence of evidential value for associations between presurgical psychological variables and postsurgical outcomes may represent a relevant avenue to consider when developing novel treatments to improve arthroplasty. There is a clear need to identify those at risk for increased disability and pain following knee replacement surgery to deliver preventative measures or explore alternative care. In particular, presurgical pain catastrophizing, depression, and anxiety may present risk factors for poor outcomes following primary joint arthroplasty. It has been shown repeatedly that these risk factors predict unique chunks of variance in outcome factors, even when strong relationships between, for example, preoperative and postoperative pain intensity are controlled for.[50,80,85] Awareness and subsequent treatment of such presurgical states may help to prevent debilitating pain and/or disability following surgery. Chronic OA-pain is exceedingly common with roughly 1 of 5 people in the UK 45 and older having sought treatment for knee-OA. Future predictions estimate that by 2035, there will be 8.3 million knee-OA sufferers alone, aged 45 and over in the UK,[2] highlighting the importance of this subject area. Up to 30% of these patients will develop increased pain and disability, despite objective indicators of surgical success[7,17,51] and presurgical psychological profiles might help identify those at risk of developing these adverse outcomes. Further research into presurgical preventative measures addressing psychological factors such as anxiety and depression is therefore a worthy cause.

To summarize, we confirmed the presence of evidential value for sets of studies examining the effects of psychosocial factors on outcomes following TKA and THA. In particular, presurgical anxiety, depression and pain catastrophizing appear to be robust predictors of higher postsurgical pain and poor functioning. Our findings could not confirm that there was evidential value underlying the link between presurgical optimism and postsurgical pain intensity for the current set of studies. Nevertheless, the link does not appear to be attributable to selective reporting, but rather, a small amount of studies investigating the relationship which do not separate findings for THA and TKA. Given the restrictions imposed by the nature of the analysis, the scarcity of relevant studies, and reporting restrictions, not all desired predictor-outcome relationships could be examined. Authors should aim to report exact *P* values and relevant statistics in order to avoid such issues in future investigations of this kind. Presurgical psychosocial factors inevitably have an effect on recovery, pain, and function postsurgery, and should be considered as risk factors which medical professionals may wish to address using preventative measures.

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